Appendix A:

EPA Updated Lake Weiss Model Calibration Results

WASP Parameters and Constants

Constants are values (such as coefficients, ratios and rates) related to the water quality constituents being simulated. Examples of constants are the nitrification rate, BOD decay rate, and denitrification temperature coefficient. As their name suggests, constants are applied to the entire model for the duration of the simulation. A table of constant values input into the WASP Model is provided in Table 1.

Table 1: WASP Input for Global Constants

PARAMETER	ON/OFF	VALUE
AMMONIA		
Nitrification Rate Constant @20 °C (per day)	1	0.2
Nitrification Temperature Coefficient	1	1.08
Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	1	1.5
Minimum Temperature for Nitrification Reaction, deg C	0	0
Ammonia Partition Coefficient to Water Column Solids, L/kg	0	0
Ammonia Partition Coefficient to Bentic Solids, L/kg	0	0
NITRITE		
Denitrification Rate Constant @ 20 °C (per day)	1	0.2
Denitrification Temperature Coefficient	1	1.08
Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	1	0.01
ORGANIC NITROGEN		
Dissolved Organic Nitrogen Mineralization Rate Constant @ 20 °C (per day)	1	0.05
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1	1.08
Organic Nitrogen Decay Rate Constant in Sediments @ 20 °C (per day)	0	0.02
Organic Nitrogen Decay in Sediment Temperature Coefficient	0	1.08
Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1	0.8
ORTHO-P		
Orthophosphate Partition Coefficient to Water Column Solids, L/kg	100	0.05
Orthophosphate Partition Coefficient to Benthic Solids, L/kg	0	1.08
ORGANIC-P		
Mineralization Rate Constant for Dissolved Organic P @ 20 °C (per day)	1	0.1
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	1	1.08
Organic Phosphorus Decay Rate Constant in Sediments @ 20 °C (per day)	0	0.02
Organic Phosphorus Decay in Sediments Temperature Coefficient	0	1.08
Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1	0.8
PHYTOPLANKTON		
Phytoplankton Maximum Growth Rate Constant @ 20 °C (per day)	1	2.5
Phytoplankton Growth Temperature Coefficient	1	1.06
Include Algal Self Shading Light Extinction in Steele (0=Yes, 1=No)	1	1
Exponent for Self Shading (Mult * TCHL A^Exp)	0	0
Multiplier for Self Shading (Mult * TCHL A^Exp)	0	0
Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0	0
Phytoplankton Carbon to Chlorophyll Ratio	1	40
Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	1	0.02
Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	1	0.002
Phytoplankton Endogenous Respiration Rate Constant @ 20 °C (per day)	1	0.1
Phytoplankton Respiration Temperature Coefficient	1	1.06
Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	1	0.02
Phytoplankton Zooplankton Grazing Rate Constant (per day)	0	0.1

Nutrient Limitation Option	0	0
Phytoplankton Decay Rate Constant in Sediments (per day)	0	0.02
Phytoplankton Temperature Coefficient for Sediment Decay	0	1.08
Phytoplankton Phosphorus to Carbon Ratio	1	0.024
Phytoplankton Nitrogen to Carbon Ratio	1	0.18
Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	1	0.1
LIGHT		
Light Option (1 uses input light; 2 uses calculated diel light)	1	2
Phytoplankton Maximum Quantum Yield Constant	1	360
Phytoplankton Optimal Light Saturation	1	350
Background Light Extinction Multiplier	1	0
Detritus & Solids Light Extinction Multiplier	1	0.017
DOC Light Extinction Multiplier	1	0.017
REAERATION		
Waterbody Type Used for Wind Driven Reaeration Rate	1	2
Calc Reaeration Option (0=Covar, 1=O'Connor, 2=Owens, 3=Churchill, 4=Tsivoglou)	1	1
Global Reaeration Rate Constant @ 20 °C (per day)	0	0
Elevation above Sea Level (meters) used for DO Saturation	0	0
Reaeration Option (Sums Wind and Hydraulic Ka)	1	1
Minimum Reaeration Rate, per day	0	0
Theta -- Reaeration Temperature Correction	1	1.024
Oxygen to Carbon Stoichiometric Ratio	1	2.667
DETRITUS		
Detritus Dissolution Rate (1/day)	1	0.1
Temperature Correction for detritus dissolution	1	1.08
CBOD1		
BOD (1) Decay Rate Constant @ 20 °C (per day)	1	0.15
BOD (1) Decay Rate Temperature Correction Coefficient	1	1.047
BOD (1) Decay Rate Constant in Sediments @ 20 °C (per day)	0	0.035
BOD (1) Decay Rate in Sediments Temperature Correction Coefficient	0	1.08
BOD (1) Half Saturation Oxygen Limit (mg O/L)	1	0.2
Fraction of Detritus Dissolution to BOD (1)	0	0
Fraction of BOD (1) Carbon Source for Denitrification	0	0
CBOD2		
BOD (2) Decay Rate @ 20 °C (per day)	1	0.015
BOD (2) Decay Rate Temperature Correction Coefficient	1	1.047
BOD (2) Decay Rate Constant in Sediments @ 20 °C (per day)	0	0.035
BOD (2) Decay Rate in Sediments Temperature Correction Coefficient	0	1.08
BOD (2) Half Saturation Oxygen Limit (mg O/L)	1	0.2
Fraction of Detritus Dissolution to BOD (2)	1	1
Fraction of BOD (2) Carbon Source for Denitrification	0	0
CBOD3		
BOD (3) Decay Rate Constant @ 20 °C (per day)	1	0.2
BOD (3) Decay Rate Temperature Correction Coefficient	1	1.047
BOD (3) Decay Rate Constant in Sediments (per day)	0	0.035
BOD (3) Decay Rate in Sediments Temperature Correction Coefficient	0	1.08
BOD (3) Half Saturation Oxygen Limit (mg O/L)	1	0.2
Fraction of Detritus Dissolution to BOD (3)	0	0
Fraction of BOD (3) Carbon Source for Denitrification	0	0

Calibration Graphs:

Growing Season 2005 was the main EPA updated WASP model calibration period. During this period GaEPD conducted extensive monitoring to establish accurate headwater and boundary model parameter input conditions. The model was run for the 2001 through 2005 period to provide an understanding of the system under various flow conditions. Also, ADEM conducted monthly Lake Weiss monitoring for 2001 through 2005.

The following figures provide a visual comparison of collected data and model output for years 2001 through 2005.

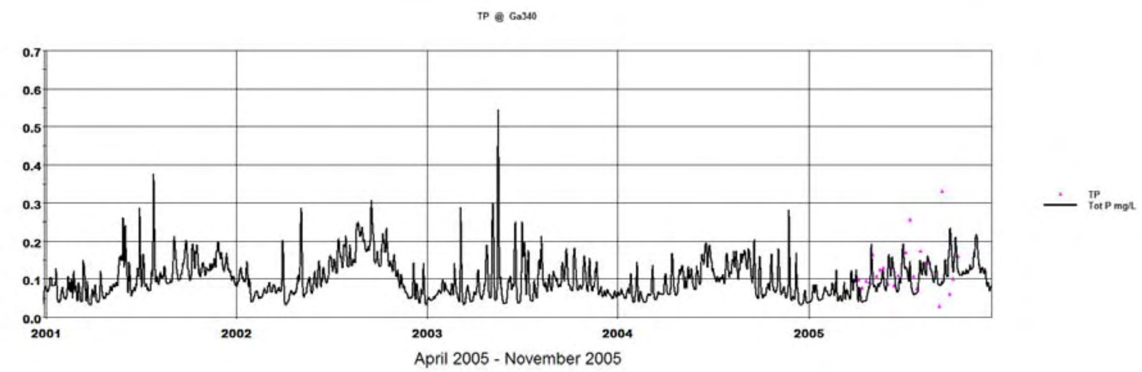

Figure 1: TP at GA340 Coosa River below Rome

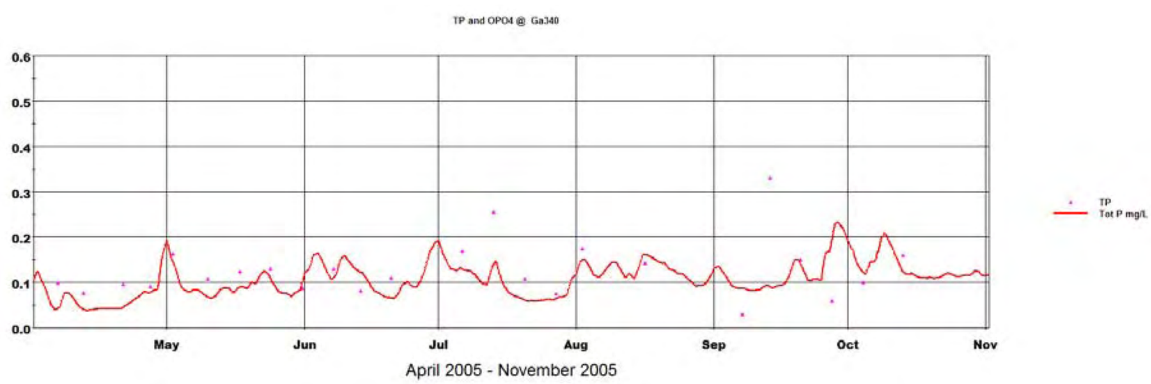

Figure 2: Growing Season 2005 TP at GA340 Coosa River below Rome

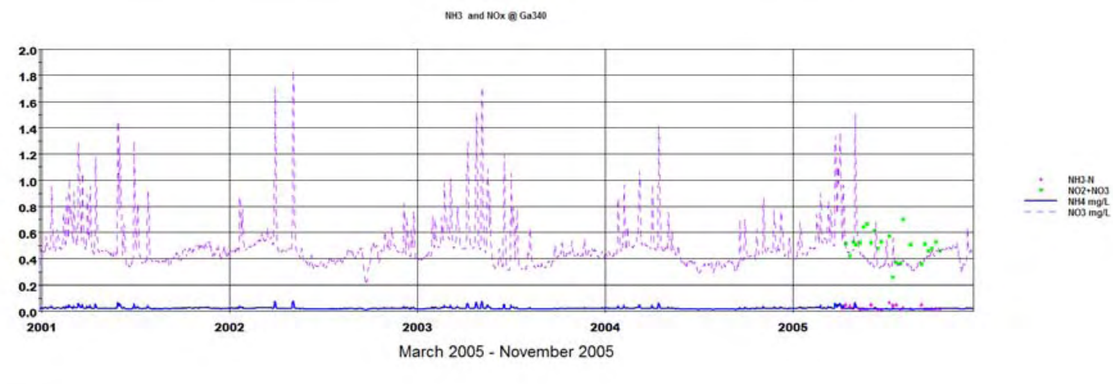

Figure 3: NOx and NH_3 at GA340 Coosa River below Rome

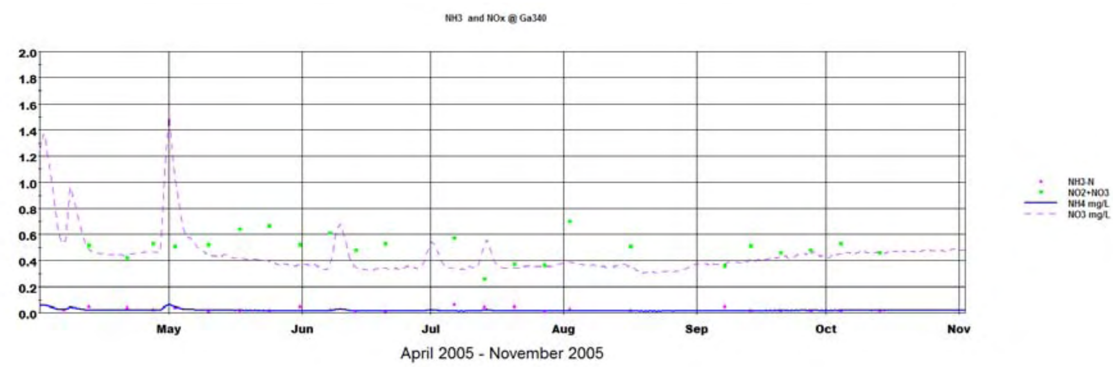

Figure 4: Growing Season 2005 NOx and NH_3 at GA340 Coosa River below Rome

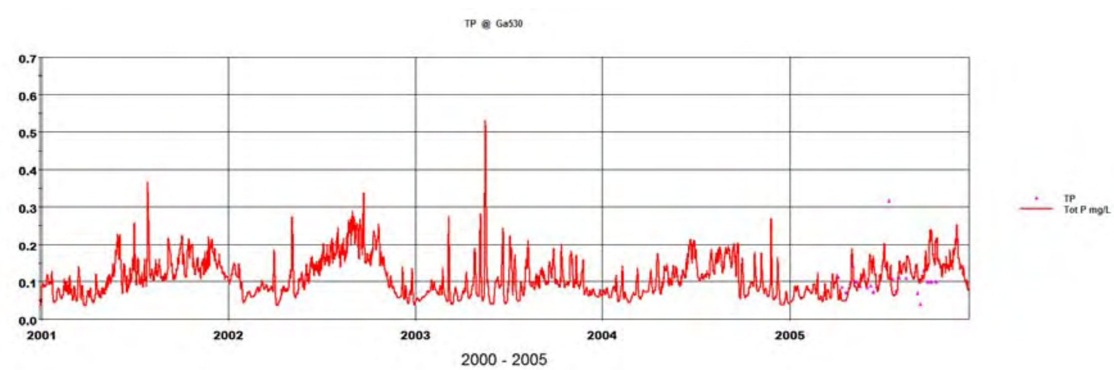

Figure 5: TP at Ga540 Coosa River near the State Line

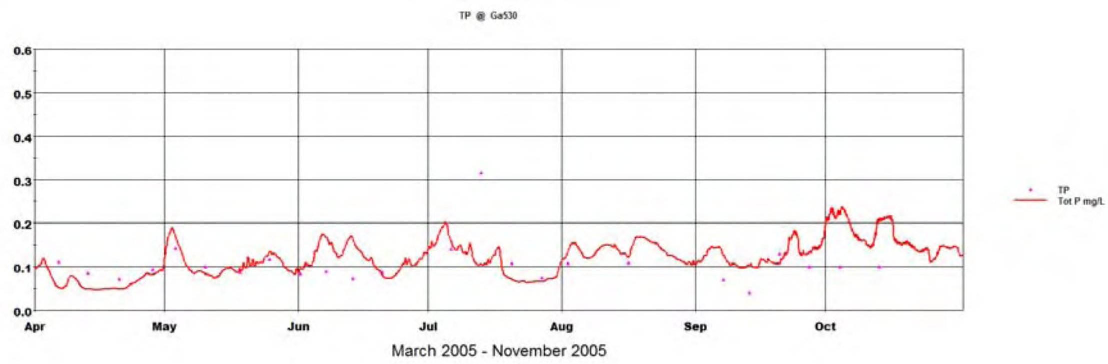

Figure 6: Growing Season TP at Ga540 Coosa River near the State Line

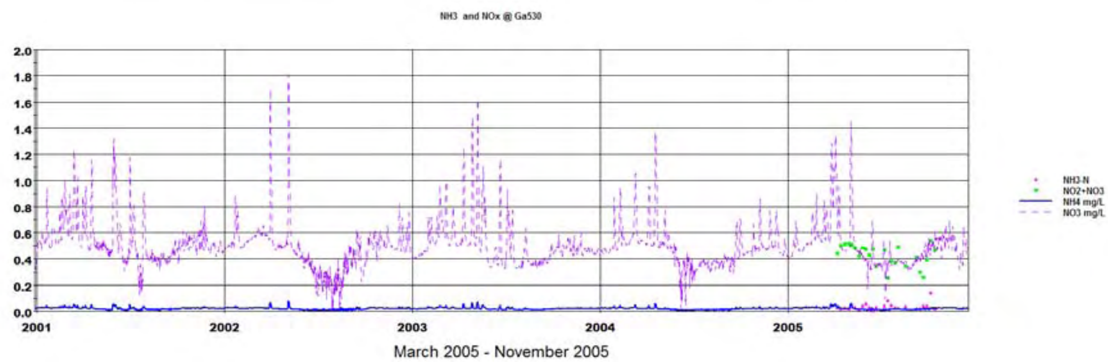

Figure 7: NOx and NH_3 at Ga540 Coosa River near the State Line

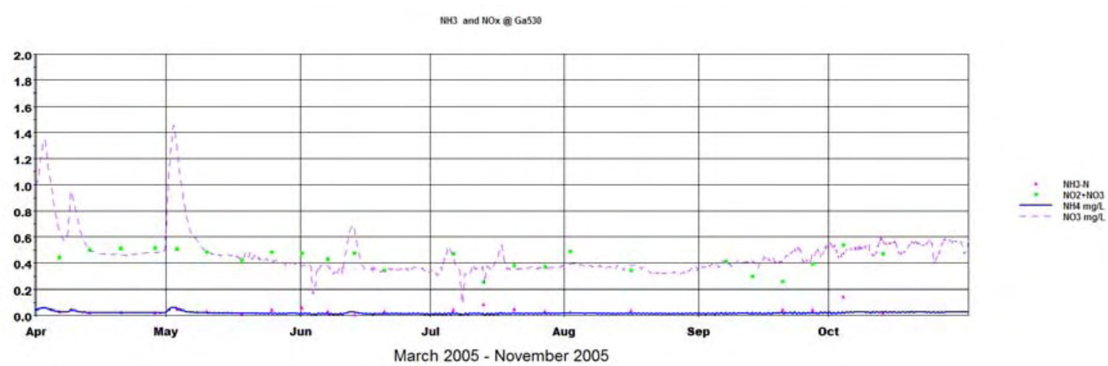

Figure 8: Growing Season NOx and NH_3 at Ga540 Coosa River near the State Line

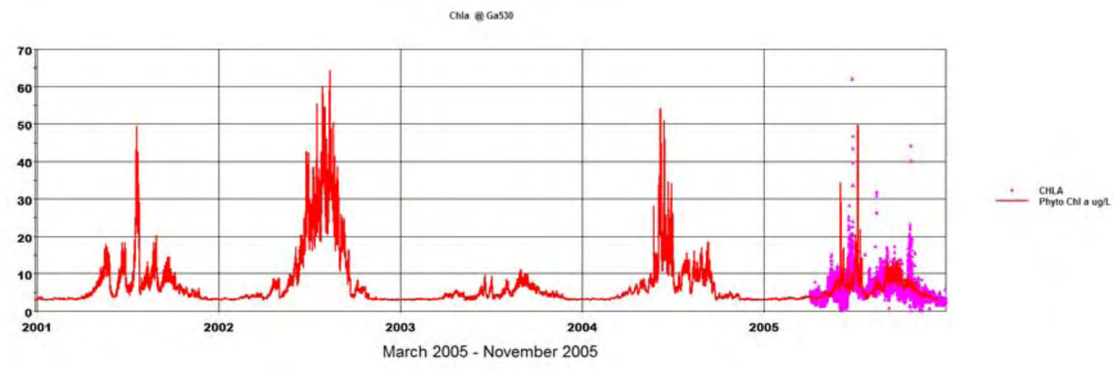

Figure 9: Chl *a* at Ga540 Coosa River near the State Line

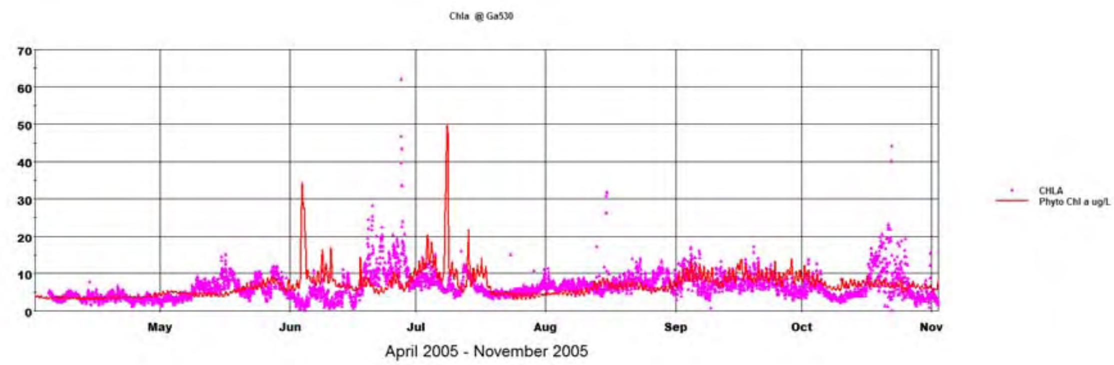

Figure 10: Growing Season 2005 Chl *a* at Ga540 Coosa River near the State Line

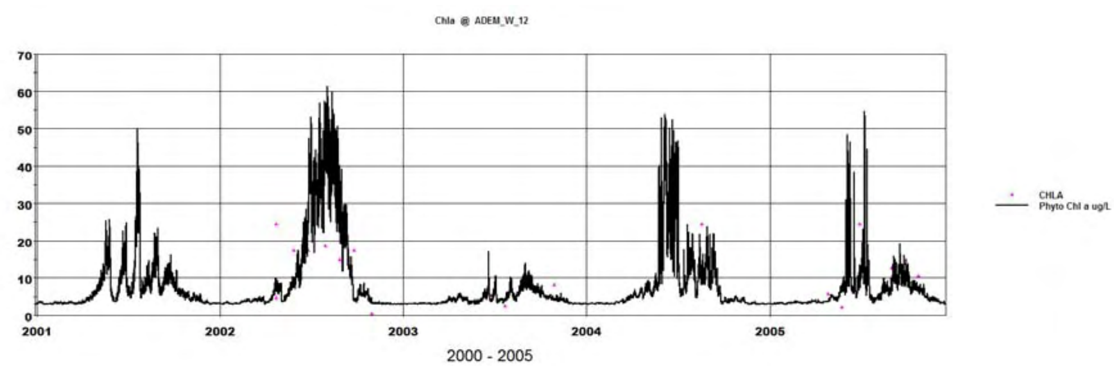

Figure 11: Chl *a* at Alabama Weiss 12 near State Line

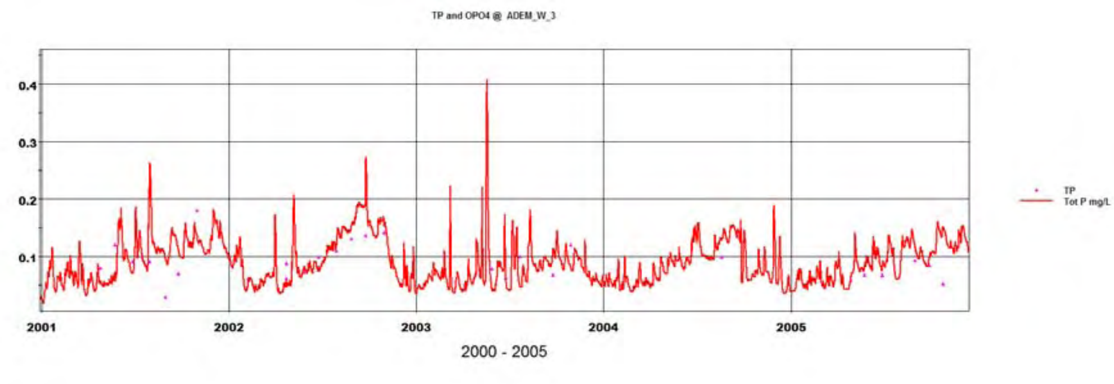

Figure 12: TP at Alabama Weiss 3 – Mid Lake Station

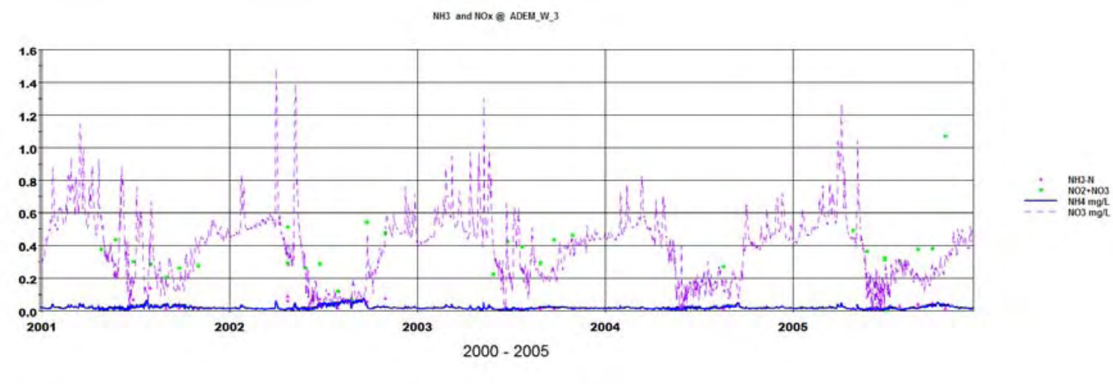

Figure 13: NOx and NH_3 at Alabama Weiss 3 – Mid Lake Station

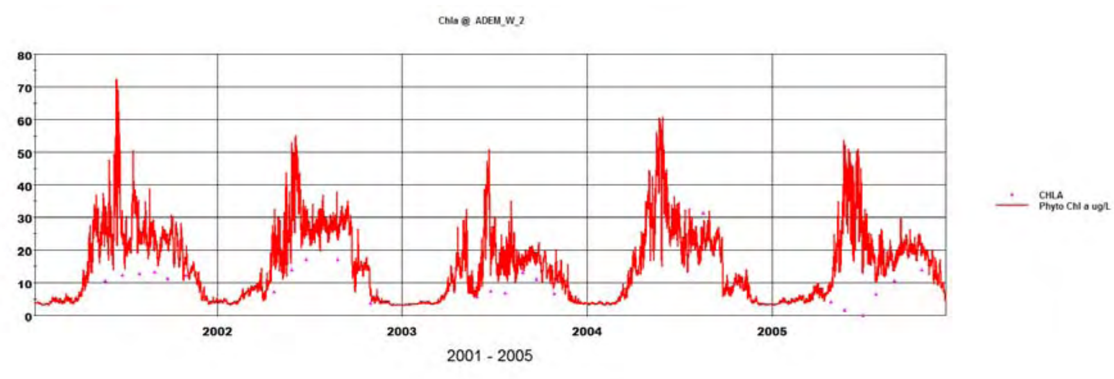

Figure 14: Chl *a* at Alabama Weiss 3 – Mid Lake Station

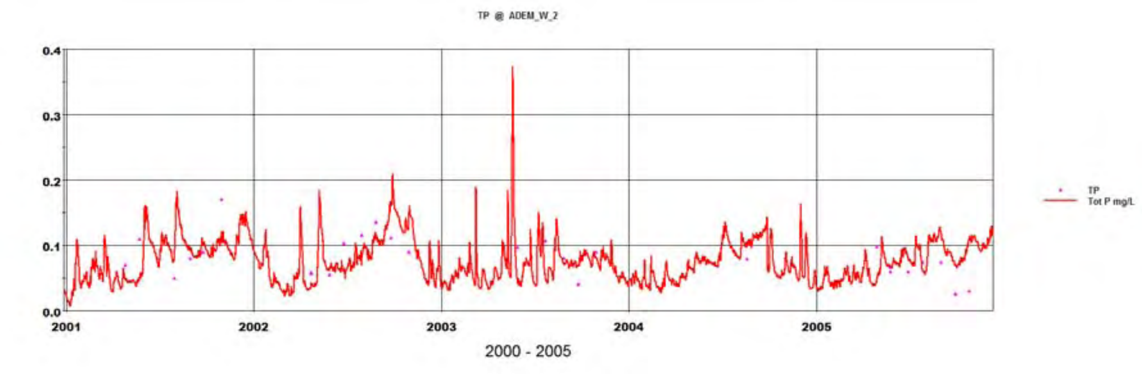

Figure 15: TP at Alabama Weiss 2 – Upper Lower Lake Monitoring Station (Critical Chl a Segment)

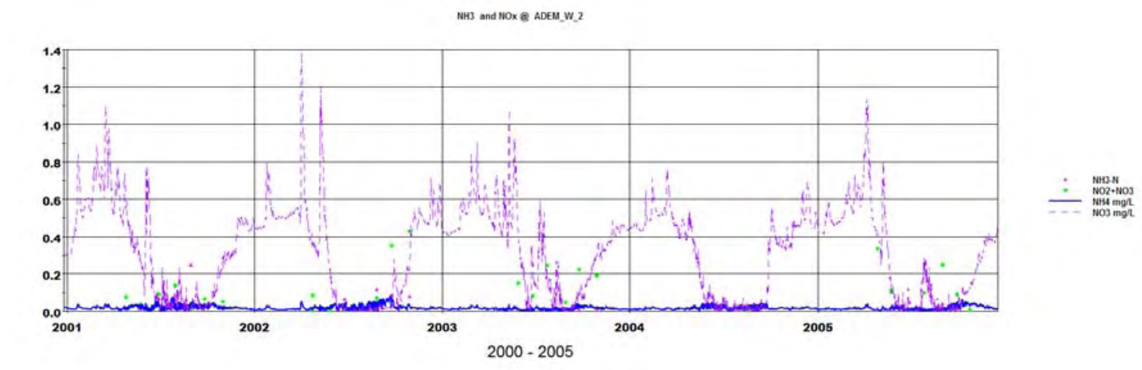

Figure 16: NOx and NH_3 at Alabama Weiss 2 – Upper Lower Lake Monitoring Station (Critical Chl a Segment)

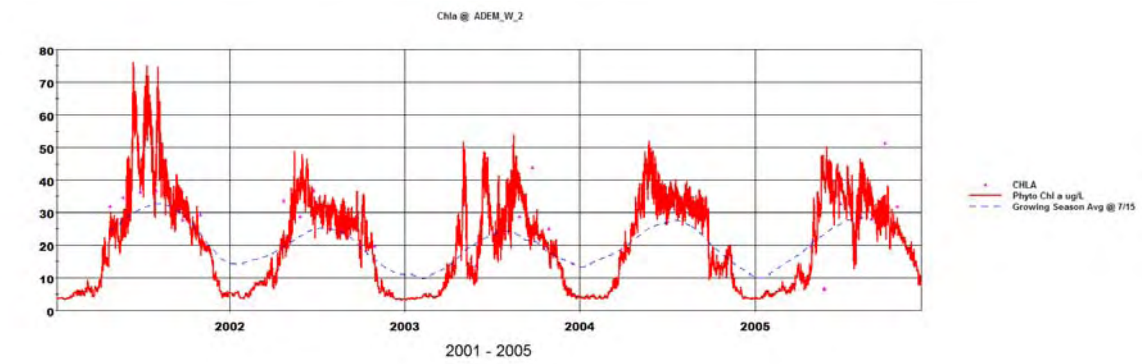

Figure 17: Chl a at Alabama Weiss 2 – Upper Lower Lake Monitoring Station (Critical Chl a Segment)

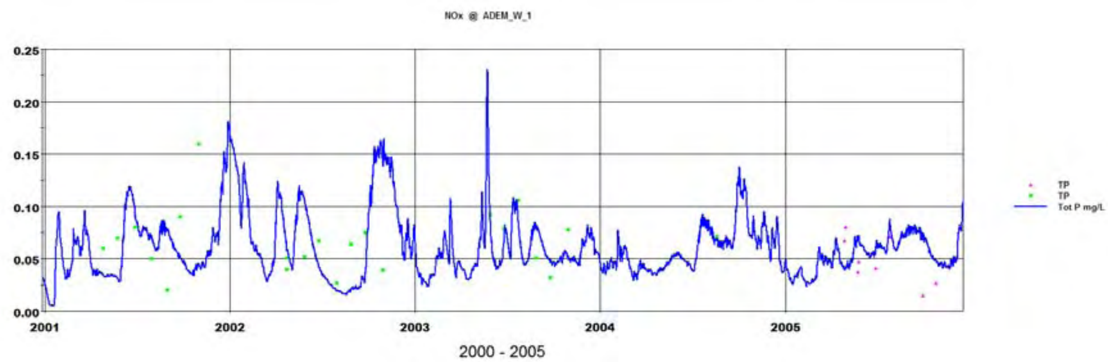

Figure 18: TP at Alabama Weiss 1 and 1a in Dam Pool Station

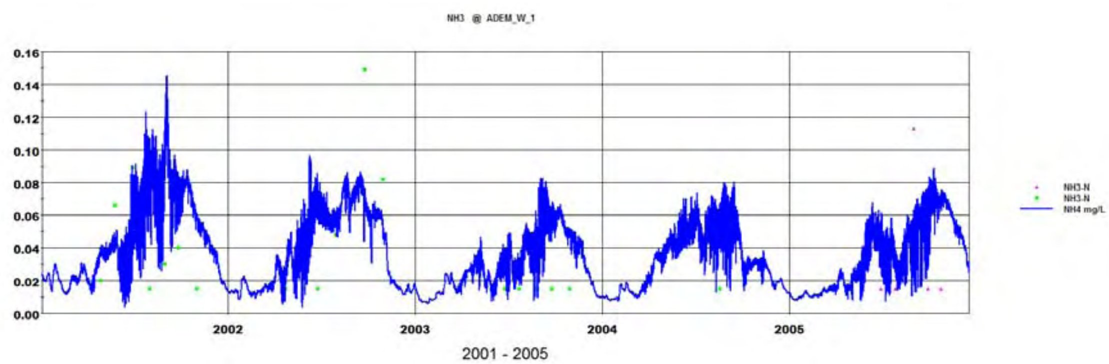

Figure 19: NH_3 at Alabama Weiss 1 and 1a in Dam Pool Station

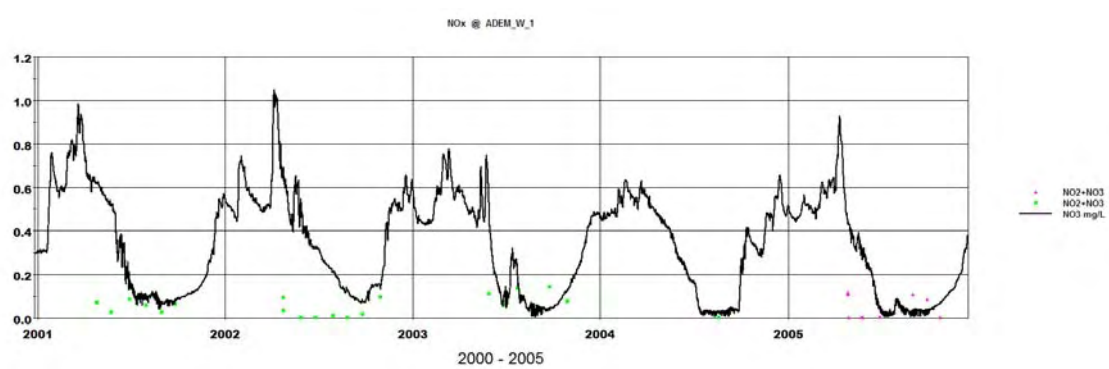

Figure 20: NOx at Alabama Weiss 1 and 1a in Dam Pool Station

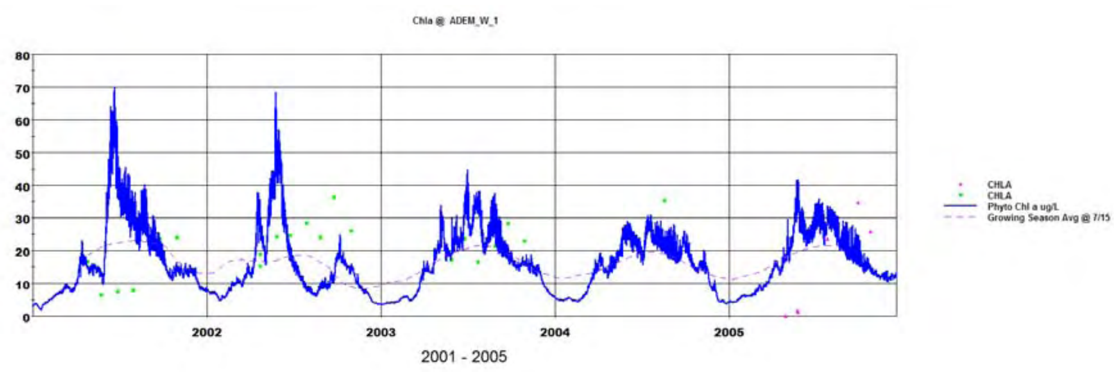

Figure 21: Chl <u>a</u> at Alabama Weiss 1 and 1a in Dam Pool Station

Lake Weiss Watershed Boundary Conditions

The Lake Weiss LSPC TMDL Watershed Model was used to determine the daily flows and nutrient concentrations for the major watersheds contributing to Lake Weiss. The upstream watersheds were included in the model to provide a tool that could estimate the inflow of water quality constituents to the headwater of the Weiss Lake hydrodynamic model. The watershed model was calibrated for hydrology using the daily flow record from a USGS gaging station located on Coosa River near Rome, Georgia (USGS 02397000). (Tt 2007)

The model was calibrated for BOD, nitrate-nitrite, ammonia, organic nitrogen, total phosphorus, and orthophosphate using observed 2005 concentration data from four tributary stations discharging to Weiss Lake (Cedar, Kings, Cabin and Beech Creeks). The model was validated using data from three additional water quality stations: Chattooga River at Mills Creek, Little River and Coosa River. The calibrated watershed model was run for the entire simulation period (January 1, 1991 – December 31, 2005) to generate a time series of water quality concentrations for the watersheds. LSPC provided concentrations for BOD, nitrate-nitrite, ammonia, organic nitrogen, orthophosphate, and total phosphorus. (Tt 2007).

Modifications to the Tt LSPC model included revising the output to just Total Nitrogen (TN) and Total Phosphorus (TP). The TN and TP were divided in to their components based on the available stream data (Table 2). These daily flows and concentrations were also inputted into an Excel spreadsheet for easy import to the WASP Model.

Table 2: TN and TP Components

Percent of TN			Percent of TP	
Org_N	NH_3	Nox	OrgP	OPO_4
0.27	0.03	0.7	0.2	0.8

In addition, the point source contributions included all the modeled parameters, not just the parameters monitored in the discharges NPDES permit. Table 3 provides the major wastewater dischargers' flows and nutrient concentrations for those located both in the Upper Coosa Headwater Watersheds and the Watersheds flowing directly to the Coosa River and Lake Weiss.

Table 3: Major Dischargers in the Watersheds
flowing directly to the Coosa River and Lake Weiss

NPDES #	Facility	Flow (mgd)	BOD_5	$CBOD_u$	NH_3	OrthoP	NO_x	OrgN
GA0030333	CALHOUN WPCP	8.5	12	48	0.5	8	2.5	0.5
GA0024091	CARTERSVILLE WPCP	11	5	20	0.5	7	2.5	0.5
GA0025721	CAVE SPRING WPCP	0.22	30	120	20	10	0	2
AL0024678	CEDAR BLUFF UB TOWN OF WWTP	0.2	40	160	3	1	15	3
GA0024074	CEDARTOWN WPCP	2.5	7.5	30	0.5	5	2.5	0.5
GA0032492	CHATSWORTH WPCP	1.5	3	12	0.5	2	2.5	0.5
AL0062723	CENTRE TOWN OF WWSB LAGOON	0.6	12	48	7	3	35	7
AL0057592	CHEROKEE CO WWTP WATER AUTH	0.1	2	8	10	5	5	5
	City of Dallas combined North and West WTFs	1.4	20	80	4	5	20	4
GA0026115	EMERSON POND	0.17	20	80	10	5	5	5
GA0025712	LAFAYETTE WPCP	2	3	12	0.3	4	1.5	0.3
GA0026042	ROCKMART WPCP	1.5	2	8	0.3	12	1.5	0.3
GA0025704	SUMMERVILLE WPCP	2	10	40	2	2	10	2
GA0025607	TRION WPCP	5	6	24	1	3	5	1

For ease of use in TMDL Development, the City of Rome point source that enters Coosa River was inputted directly in the Lake Weiss model as a WASP load, as were the other direct dischargers. The LSPC model was run without this discharger and the LSPC concentrations were entered as WASP main stem or boundary conditions.

The following sections provide the individual watersheds flows and the nitrogen and phosphorous concentrations in figure and tabular forms.

Upper Coosa River below Rome:

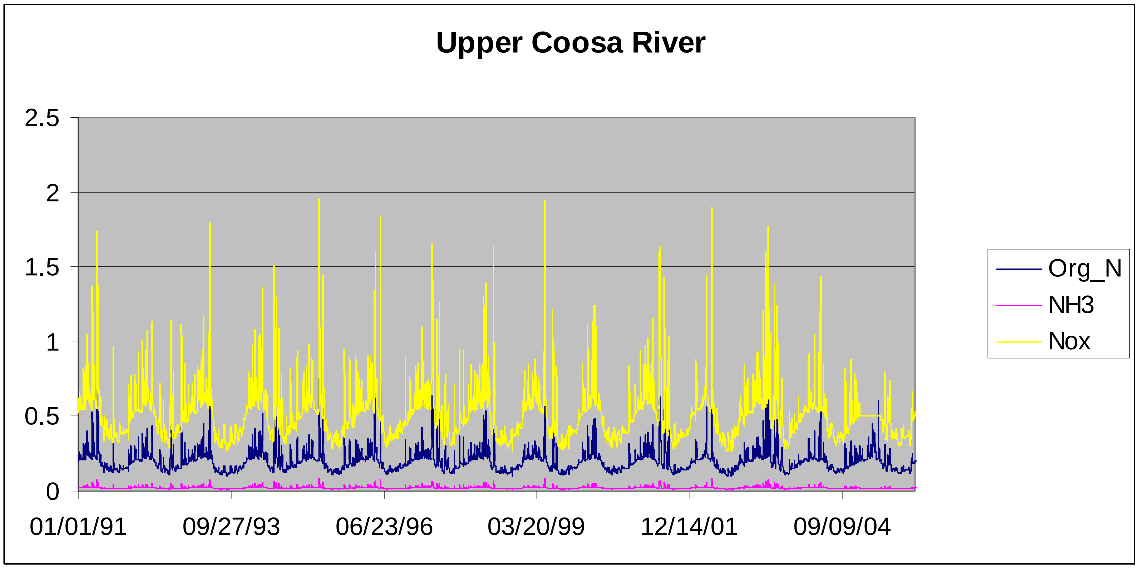

Figure 22: Nitrogen Concentrations for Upper Coosa River below Rome, Georgia

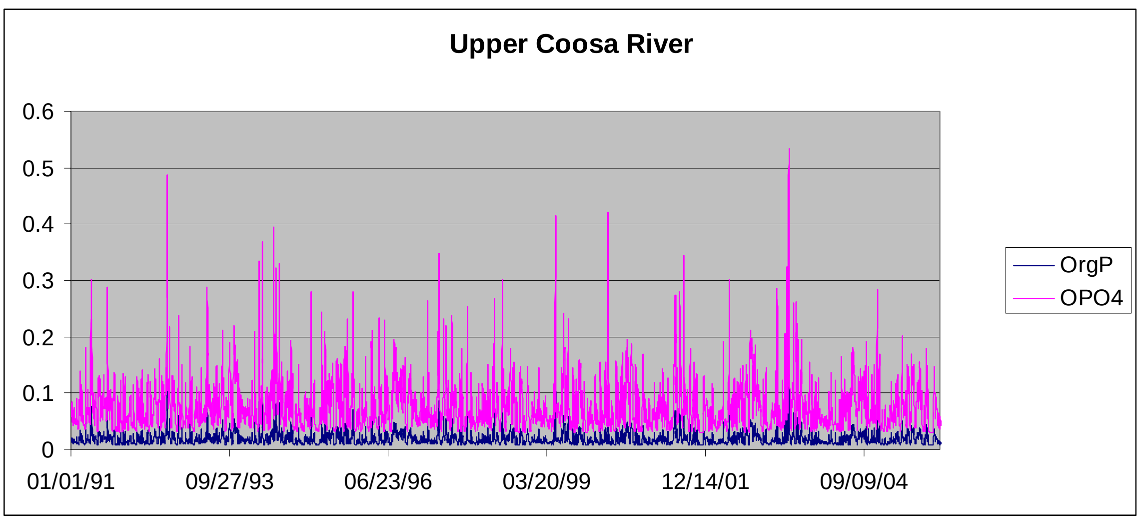

Figure 23: Phosphorous Concentrations for Upper Coosa River below Rome, Georgia

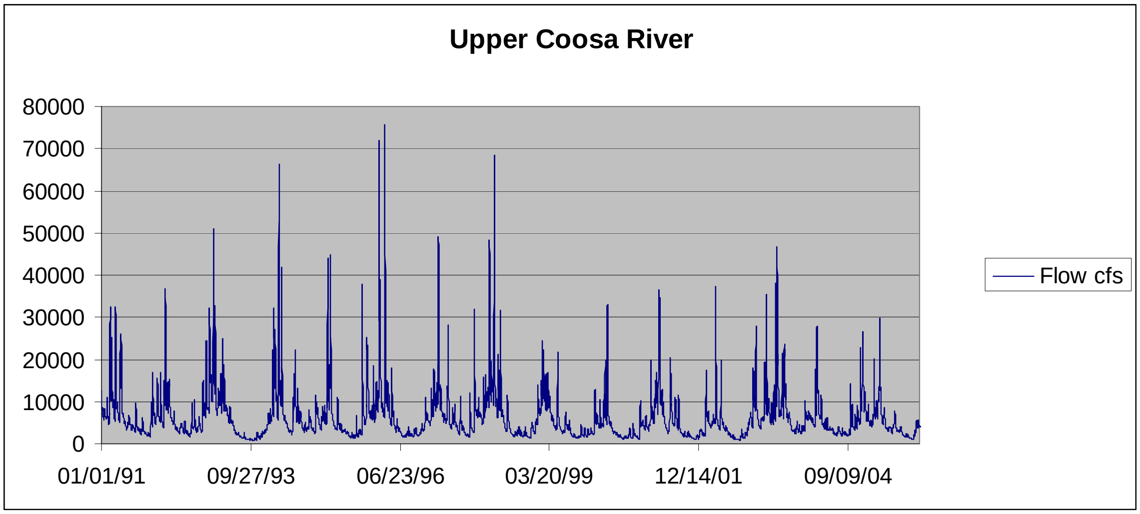

Figure 24: Flows for Upper Coosa River below Rome, Georgia

Table 4: Summary Flows and the Nitrogen and Phosphorus Concentrations for Upper Coosa River below Rome, Georgia

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	6224	0.71	0.080	23451	2665
1997	5839	0.72	0.075	22372	2341
2000	2888	0.67	0.074	10331	1141
2001	3841	0.71	0.078	14491	1605
2002	3594	0.72	0.083	13810	1602
2003	6183	0.75	0.078	24798	2578
2004	4107	0.72	0.079	15698	1734
2005	4045	0.68	0.079	14766	1711

Beech, King and Cabin Creeks:

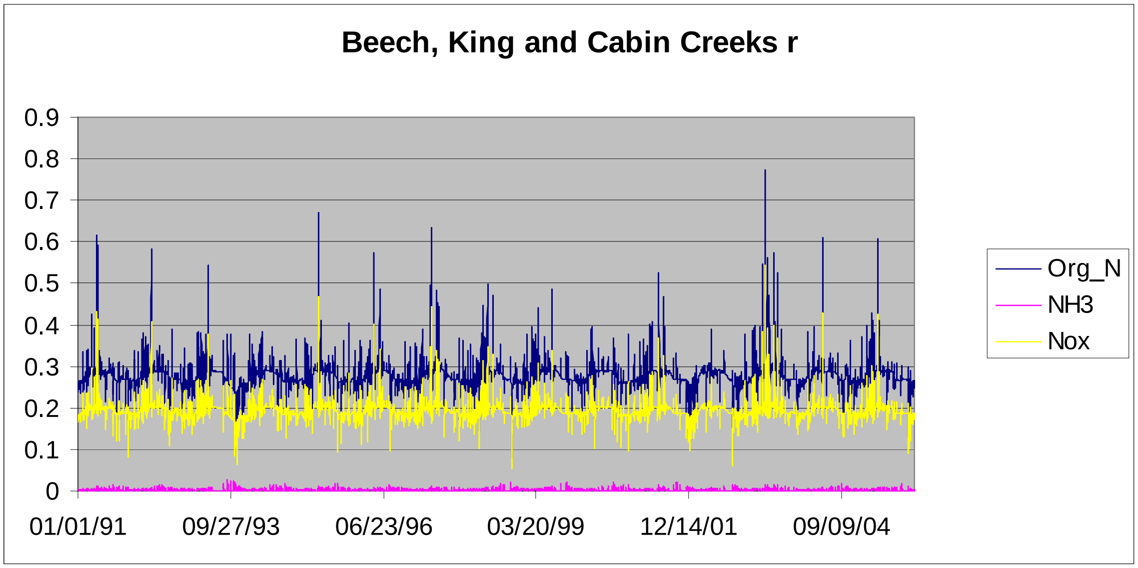

Figure 25: Nitrogen Concentrations for Beech, King and Cabin Creeks

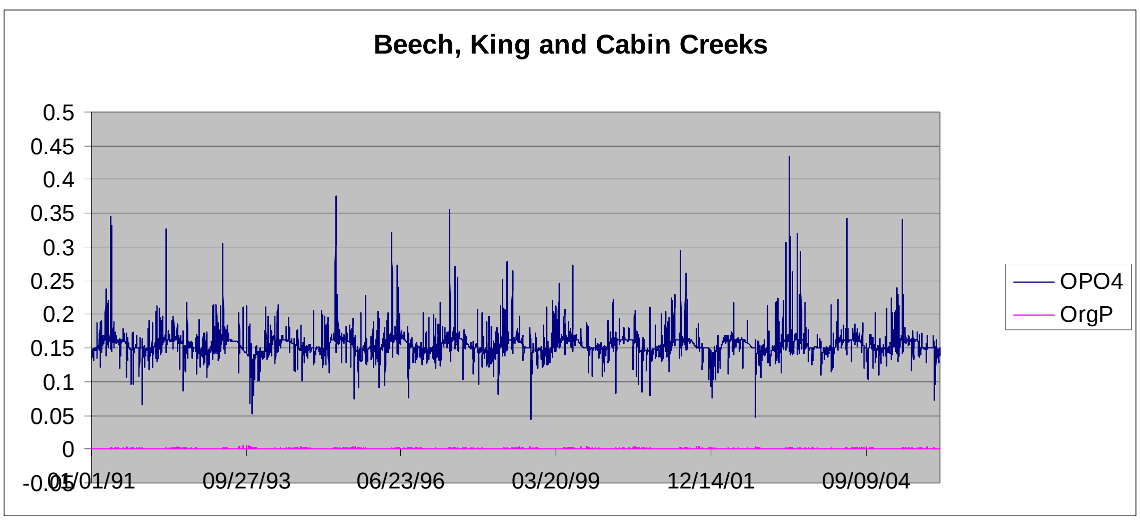

Figure 26: Phosphorus Concentrations for Beech, King and Cabin Creeks

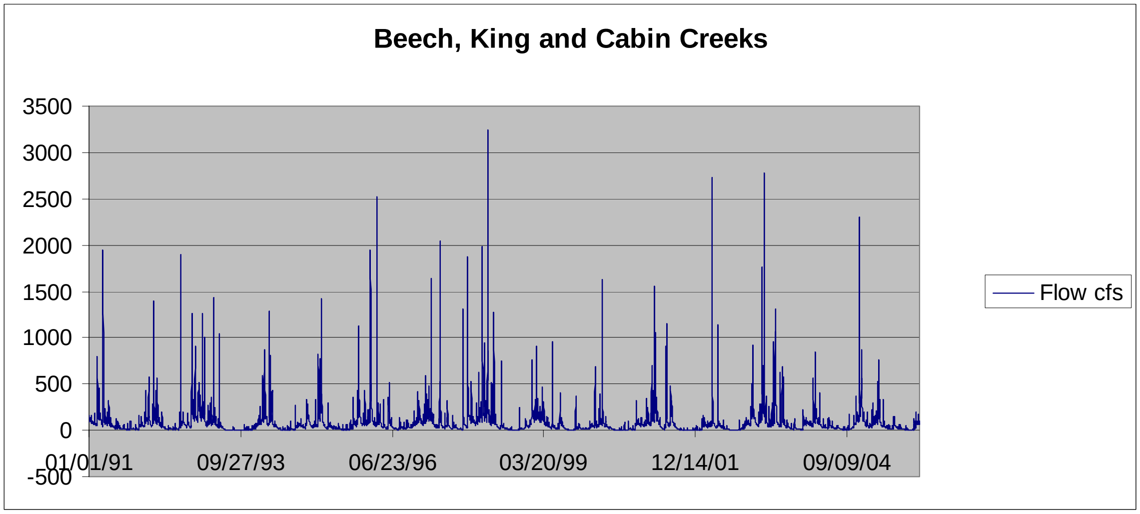

Figure 27: Flows for Beech, King and Cabin Creeks

Table 5: Summary Flows and the Nitrogen and Phosphorus Concentrations for Beech, King and Cabin Creeks

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	84	0.46	0.152	207	68
1997	61	0.46	0.152	149	49
2000	25	0.46	0.153	62	21
2001	36	0.46	0.152	88	29
2002	36	0.47	0.154	90	29
2003	66	0.46	0.151	162	53
2004	40	0.48	0.156	102	34
2005	38	0.46	0.151	92	30

Cedar Creek:

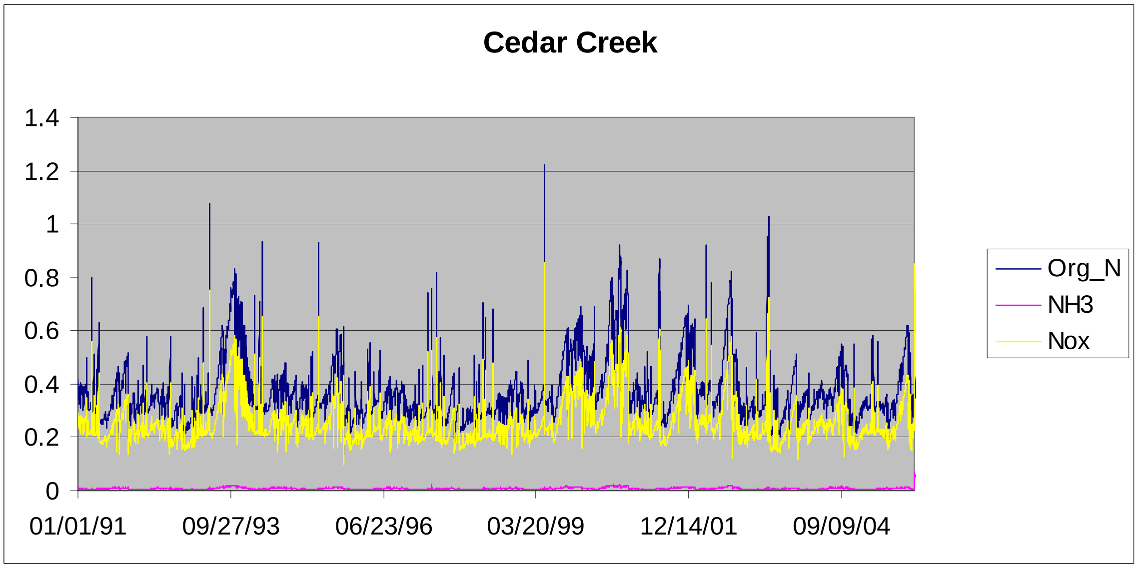

Figure 28: Nitrogen Concentrations for Cedar Creek

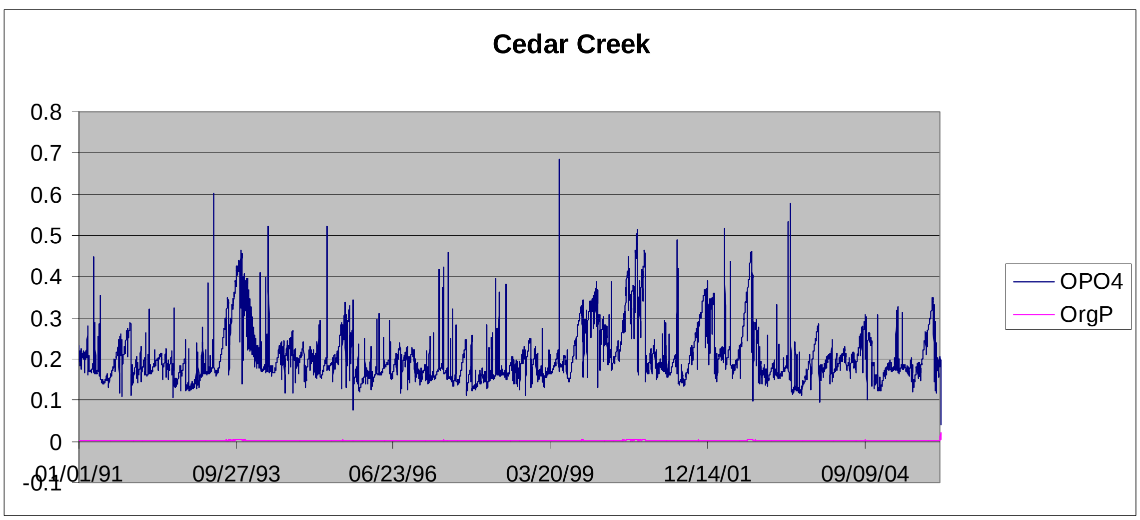

Figure 29: Phosphorus Concentrations for Cedar Creek

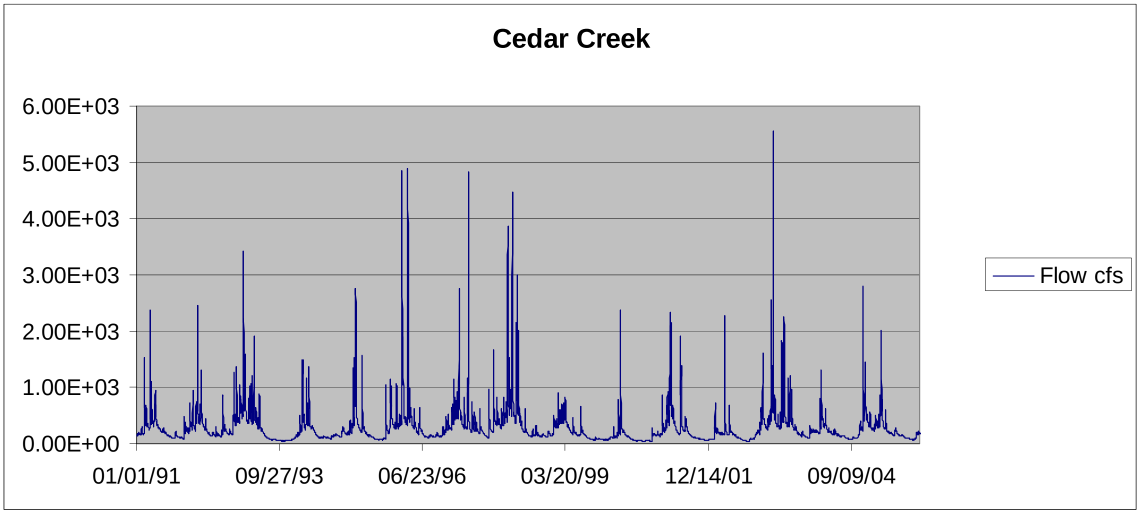

Figure 30: Flows for Cedar Creek

Table 6: Summary Flows and the Nitrogen and Phosphorus Concentrations for Cedar Creek

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	291	0.57	0.187	884	290
1997	321	0.49	0.161	838	275
2000	101	0.83	0.271	446	146
2001	178	0.60	0.196	571	187
2002	158	0.66	0.217	557	183
2003	299	0.51	0.168	819	269
2004	187	0.60	0.196	597	196
2005	190	0.56	0.183	567	185

Chattooga River:

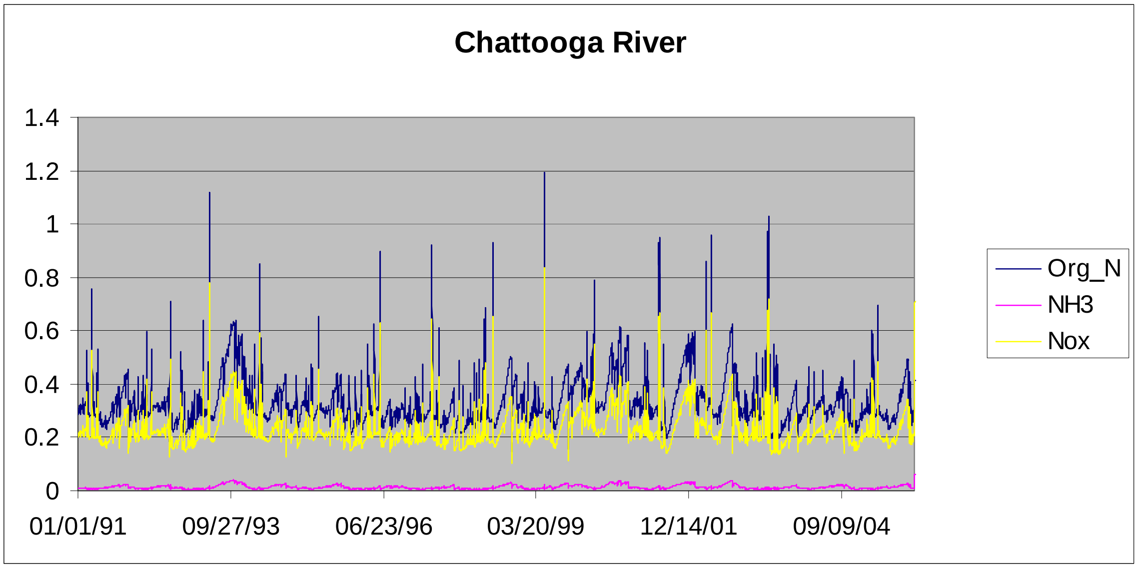

Figure 31: Nitrogen Concentrations for Chattooga River

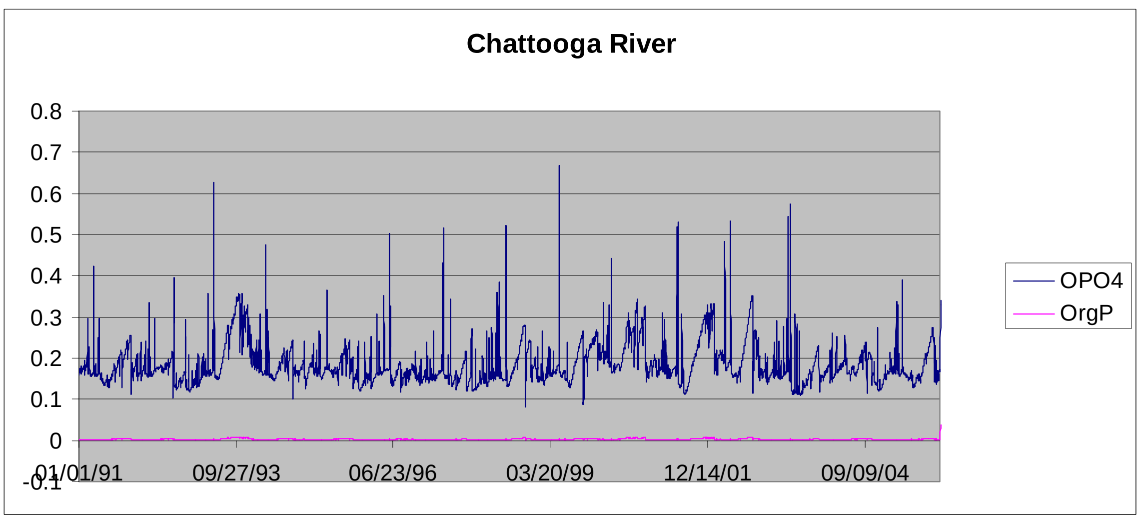

Figure 32: Phosphorus Concentrations for Chattooga River

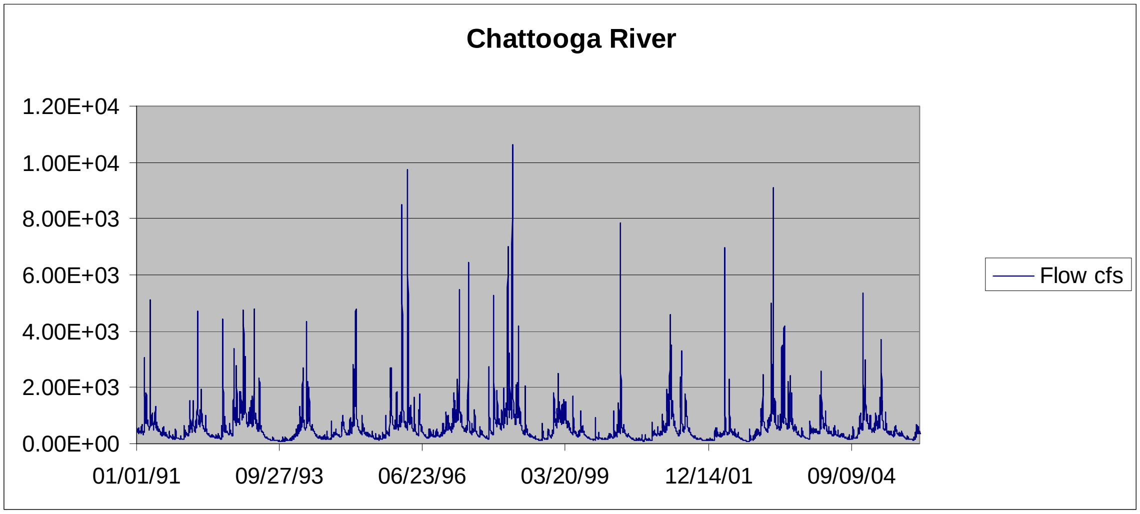

Figure 33: Flows for Chattooga River

Table 7: Summary Flows and the Nitrogen and Phosphorus Concentrations for Chattooga River

Year	**Median Value**				
	Flow (cfs)	**TN (mg/L)**	**TP (mg/L)**	**TN (#/day)**	**TP (#/day)**
1991 - 2005	575	0.52	0.171	1609	526
1997	545	0.47	0.154	1371	448
2000	238	0.66	0.216	841	274
2001	386	0.55	0.179	1128	369
2002	286	0.61	0.198	927	302
2003	562	0.48	0.158	1447	473
2004	370	0.53	0.173	1050	343
2005	394	0.51	0.165	1062	347

South of Lake Watershed:

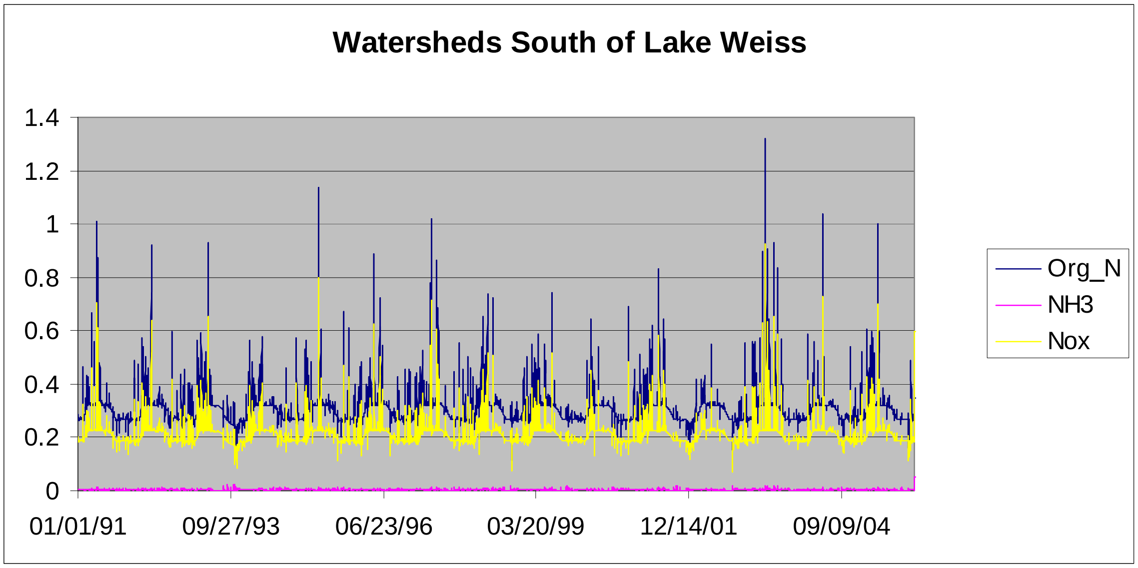

Figure 34: Nitrogen Concentrations for South of Lake Watersheds

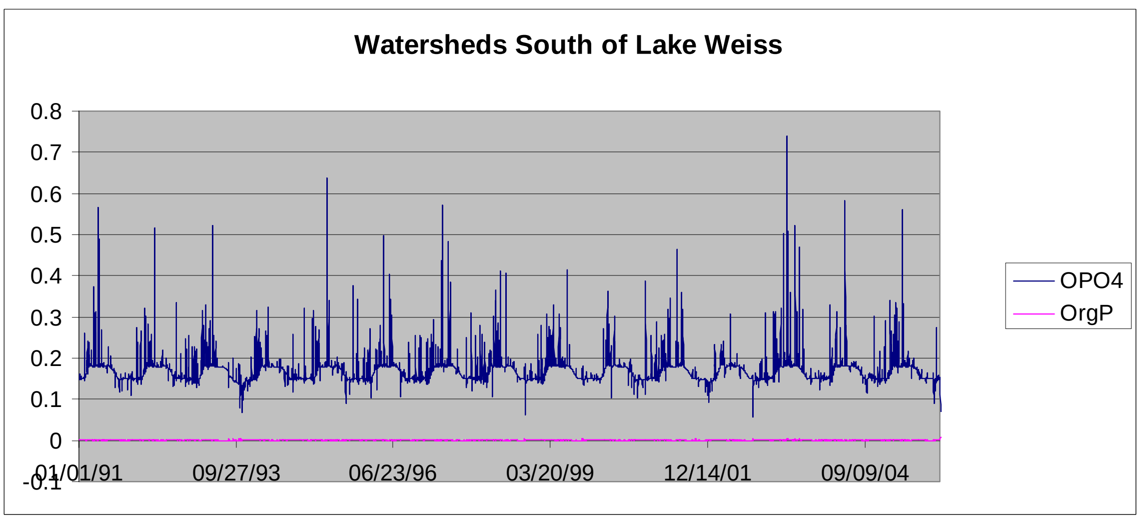

Figure 35: Phosphorus Concentrations for South of Lake Watersheds

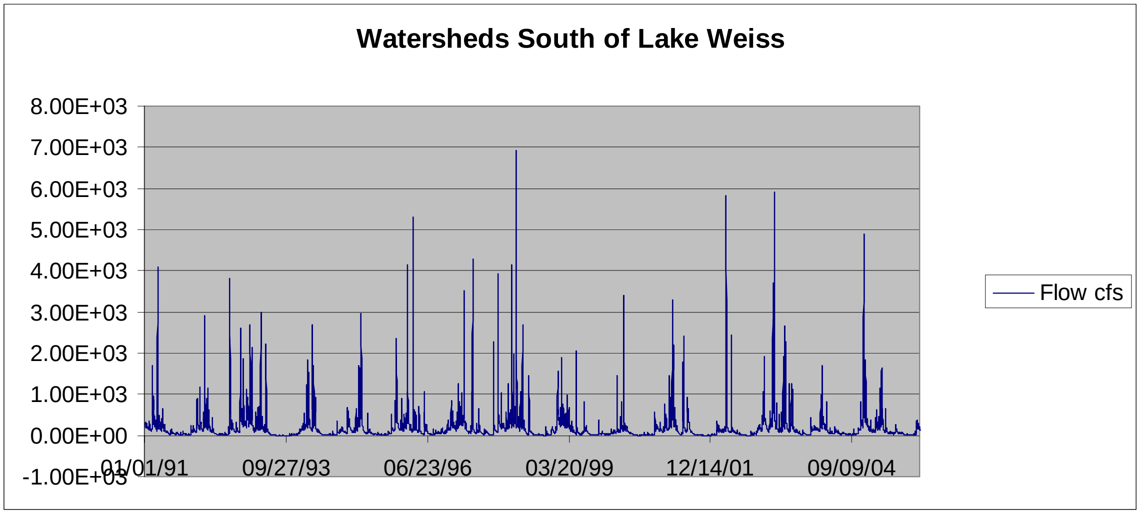

Figure 36: Flows for South of Lake Watersheds

Table 8: Summary Flows and the Nitrogen and Phosphorus Concentrations for South of Lake Watersheds

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	178	0.51	0.166	481	158
1997	125	0.51	0.167	341	112
2000	50	0.49	0.161	132	43
2001	75	0.51	0.167	205	67
2002	75	0.50	0.166	201	66
2003	139	0.51	0.167	378	124
2004	84	0.51	0.168	229	75
2005	74	0.50	0.165	198	65

Spring Creek Watersheds:

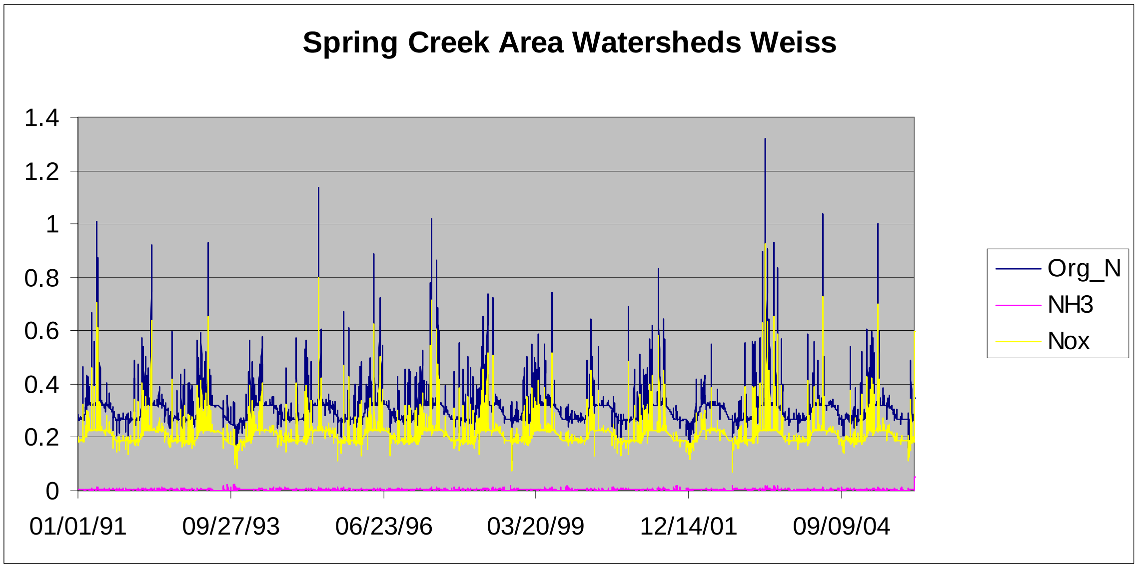

Figure 37: Nitrogen Concentrations for Spring Creek

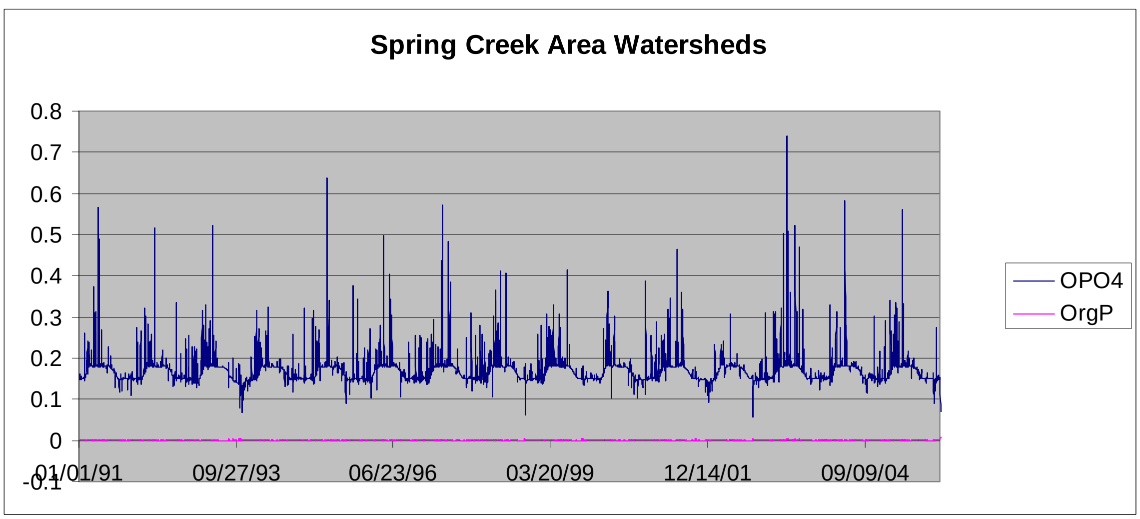

Figure 38: Phosphorus Concentrations for Spring Creek

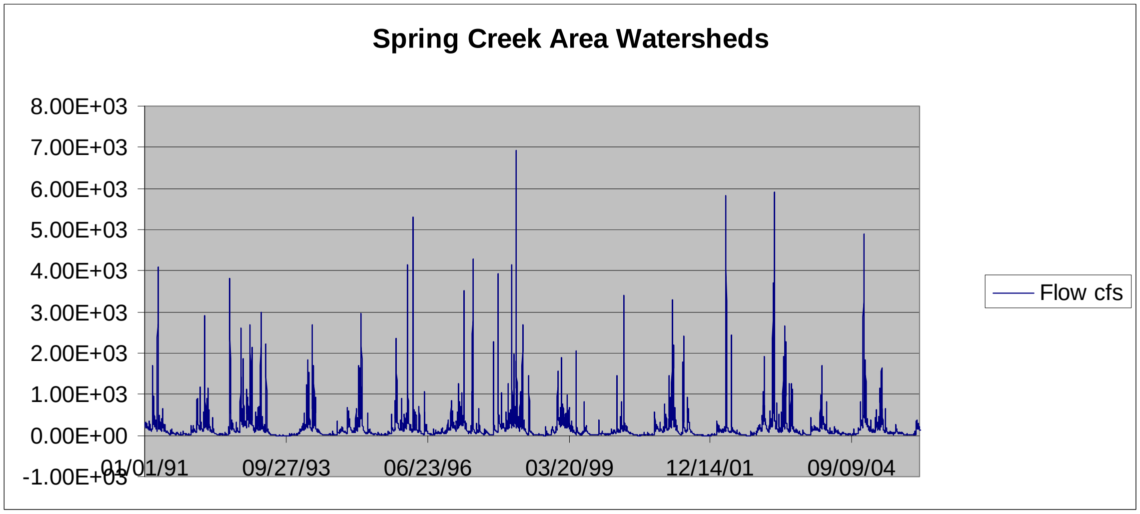

Figure 39: Flows for Spring Creek

Table 9: Summary Flows and the Nitrogen and Phosphorus Concentrations for Spring Creek

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	178	0.51	0.166	481	158
1997	125	0.51	0.167	341	112
2000	50	0.49	0.161	132	43
2001	75	0.51	0.167	205	67
2002	75	0.50	0.166	201	66
2003	139	0.51	0.167	378	124
2004	84	0.51	0.168	229	75
2005	74	0.50	0.165	198	65

Little River and Mud Creek Watershed:

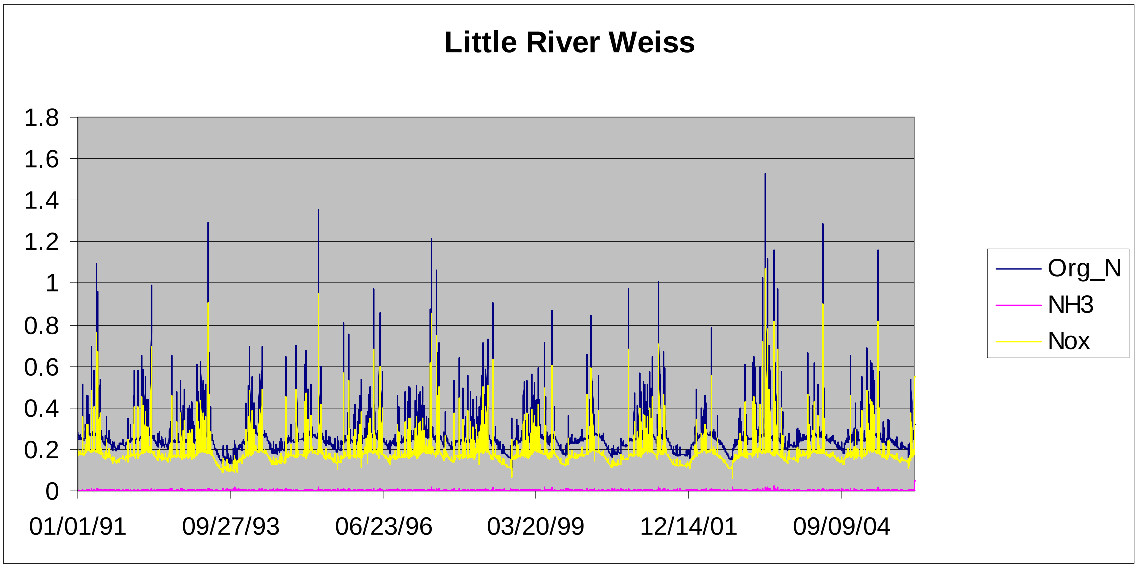

Figure 40: Nitrogen Concentrations for Little River and Mud Creek Watersheds

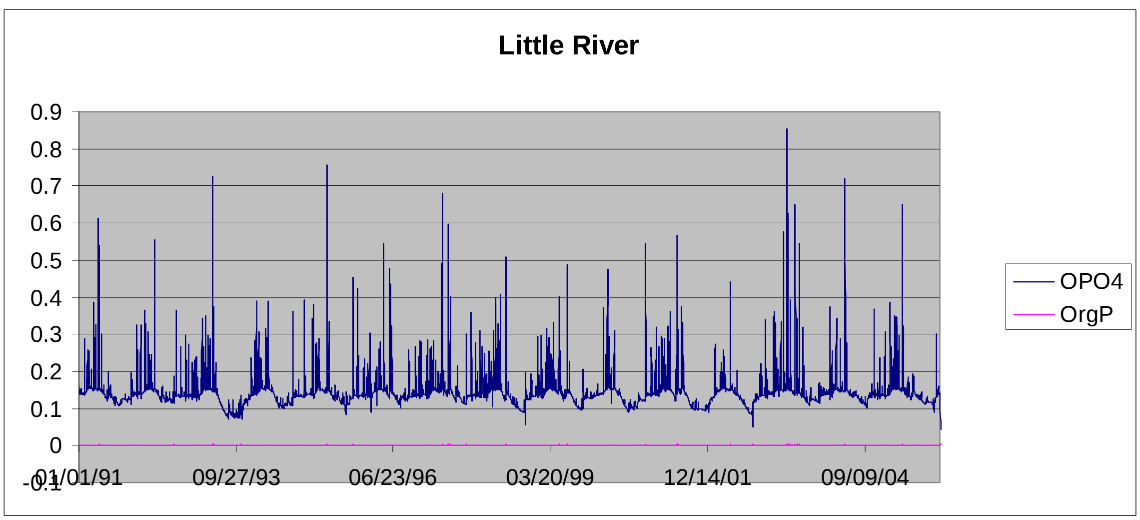

Figure 41: Phosphorus Concentrations for Little River and Mud Creek Watersheds

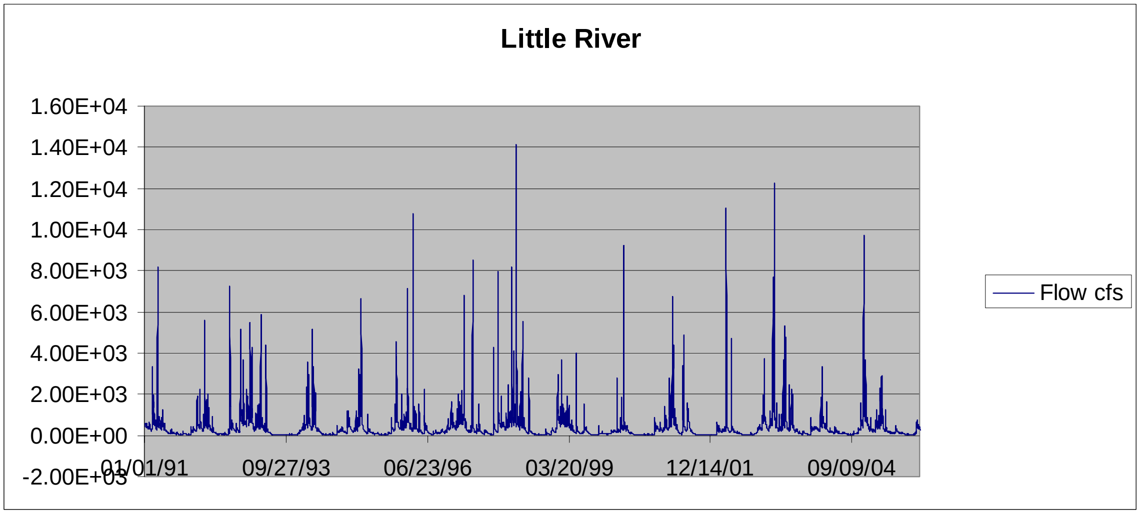

Figure 42: Flows for Little River and Mud Creek Watersheds

Table 10: Summary Flows and the Nitrogen and Phosphorus Concentrations for Little River and Mud Creek

Year	Median Value				
	Flow (cfs)	**TN (mg/L)**	**TP (mg/L)**	**TN (#/day)**	**TP (#/day)**
1991 – 2005	385	0.42	0.137	855	281
1997	290	0.42	0.139	654	215
2000	116	0.41	0.136	257	84
2001	181	0.42	0.139	408	134
2002	162	0.41	0.136	358	118
2003	316	0.43	0.140	719	236
2004	189	0.42	0.139	425	140
2005	174	0.42	0.137	386	127

Watersheds Lower North of Lake Weiss including Yellow River:

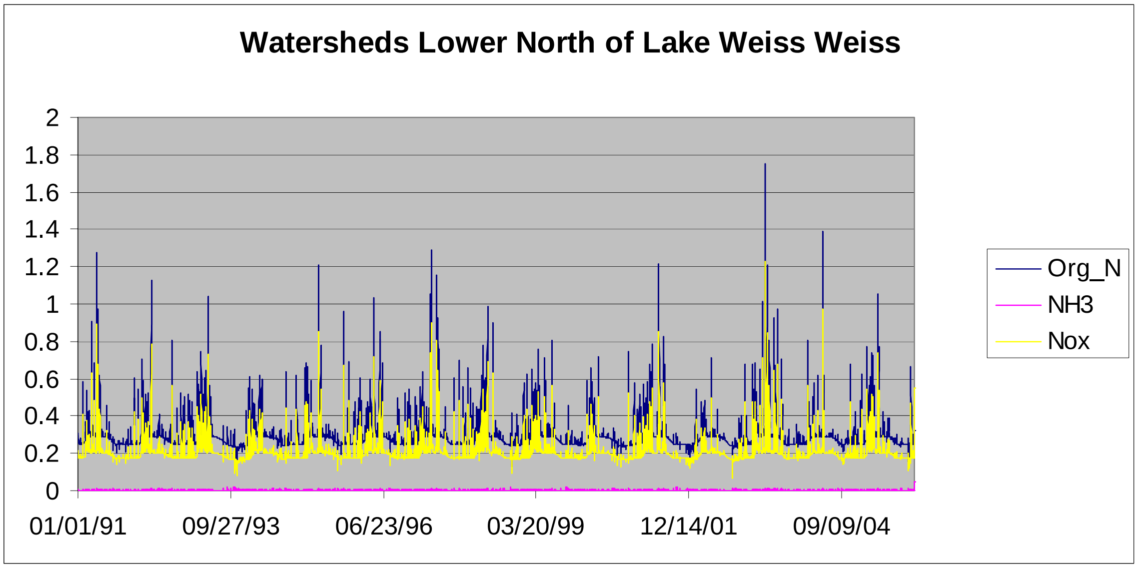

Figure 43: Nitrogen Concentrations for Lower Northern Watersheds

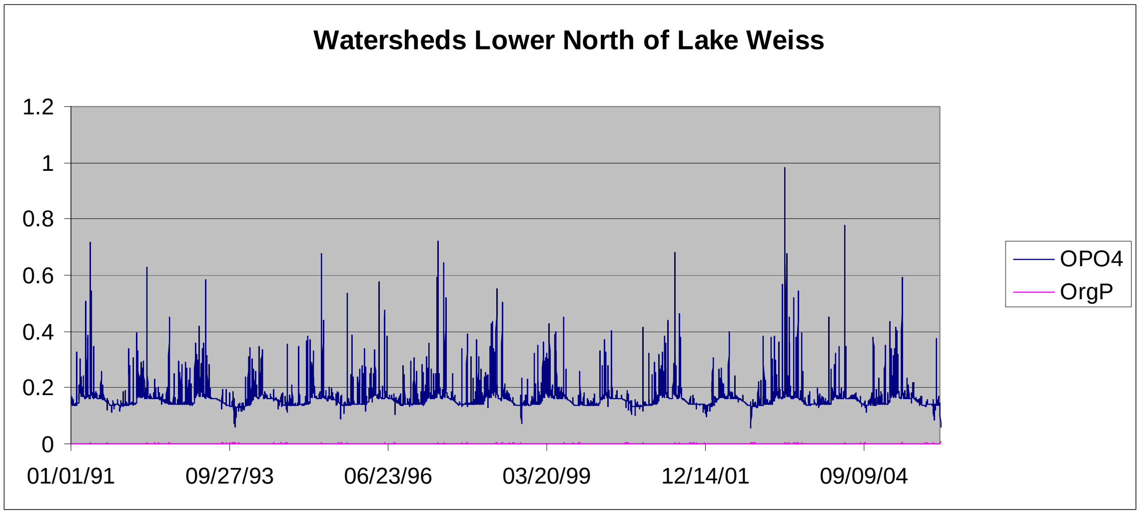

Figure 44: Phosphorus Concentrations for Lower Northern Watersheds

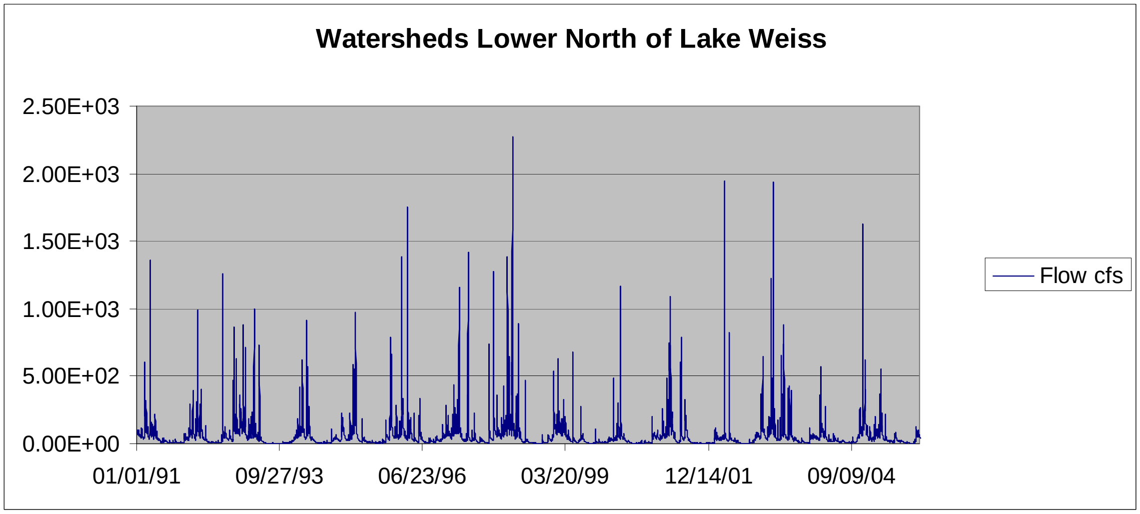

Figure 45: Flows for Lower Northern Watersheds

Table 11: Summary Flows and the Nitrogen and Phosphorus Concentrations for Lower Northern Watersheds

Year	Median Value				
	Flow (cfs)	**TN (mg/L)**	**TP (mg/L)**	**TN (#/day)**	**TP (#/day)**
1991 – 2005	58	0.47	0.155	146	48
1997	41	0.48	0.159	106	35
2000	16	0.47	0.153	41	13
2001	25	0.47	0.154	61	20
2002	24	0.47	0.153	60	20
2003	45	0.48	0.159	116	38
2004	27	0.48	0.157	69	23
2005	24	0.47	0.153	60	20

Lower South Watersheds:

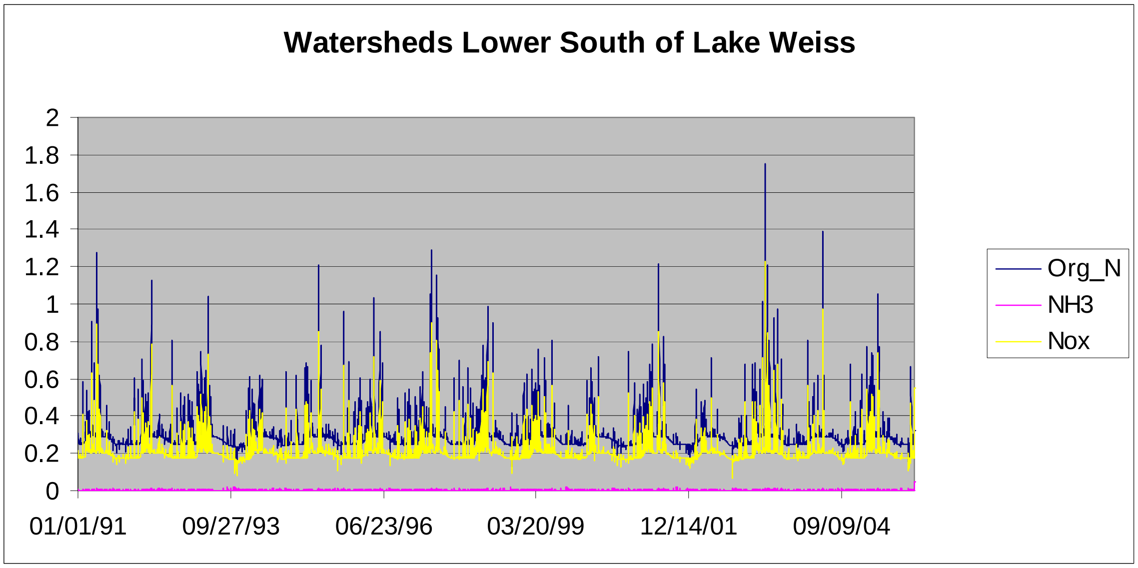

Figure 46: Nitrogen Concentrations for Lower Southern Watersheds

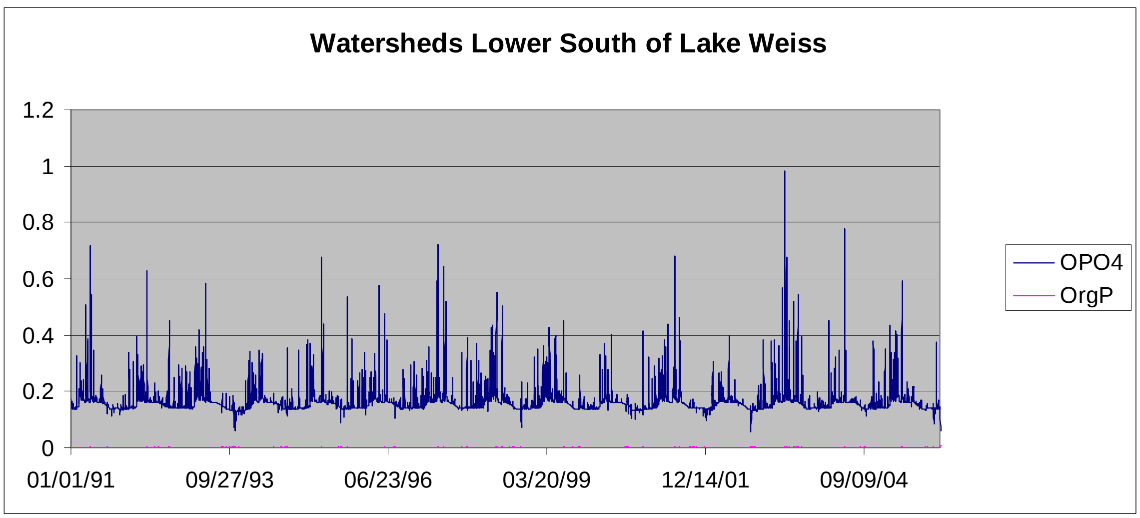

Figure 47: Phosphorus Concentrations for Lower Southern Watersheds

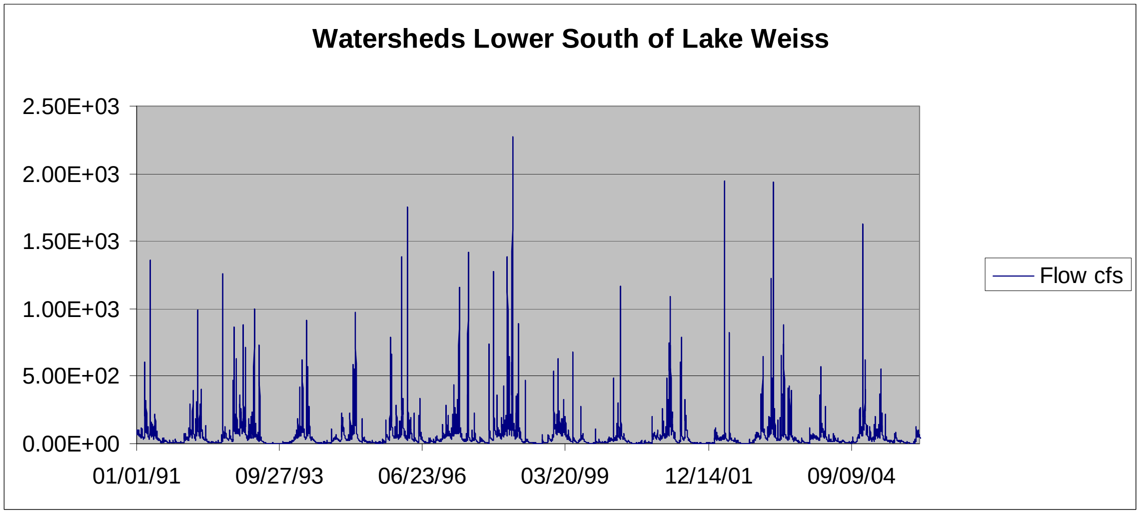

Figure 48: Flows for Lower Southern Watersheds

Table 12: Summary Flows and the Nitrogen and Phosphorus Concentrations for Lower Southern Watersheds

Year	Median Value				
	Flow (cfs)	TN (mg/L)	TP (mg/L)	TN (#/day)	TP (#/day)
1991 - 2005	58	0.47	0.155	146	48
1997	41	0.48	0.159	106	35
2000	16	0.47	0.153	41	13
2001	25	0.47	0.154	61	20
2002	24	0.47	0.153	60	20
2003	45	0.48	0.159	116	38
2004	27	0.48	0.157	69	23
2005	24	0.47	0.153	60	20

Appendix B:

Lake Weiss TMDL Model – July 2008

The 2001 – 2005 EPA updated Lake Weiss model was used for TMDL development and reduction scenarios. Note there are many ways to reduce phosphorus for this TMDL. The example methodology used for Point and Non Point Sources phosphorus reductions are as follows:

1. Major Point Sources set to 1 mg/L Total Phosphorus
2. Minor Point Sources (> 0.1 mgd) set to 8.34 lbs/day max
3. Minor Point Sources (< 0.1 mgd) set at existing values or estimations
4. Non Point Source reductions at 30% for all watersheds. Note: this could vary for implementation purposes as long as overall loads do not change.
5. Alabama Weiss 2 Monitoring Station is the critical segment in which to meet the Chl a Standard of 20 µg/L.

The following figures and tables visual show how the critical segment Chl a and the Total Phosphorous at the State Line responds to the above phosphorous reductions.

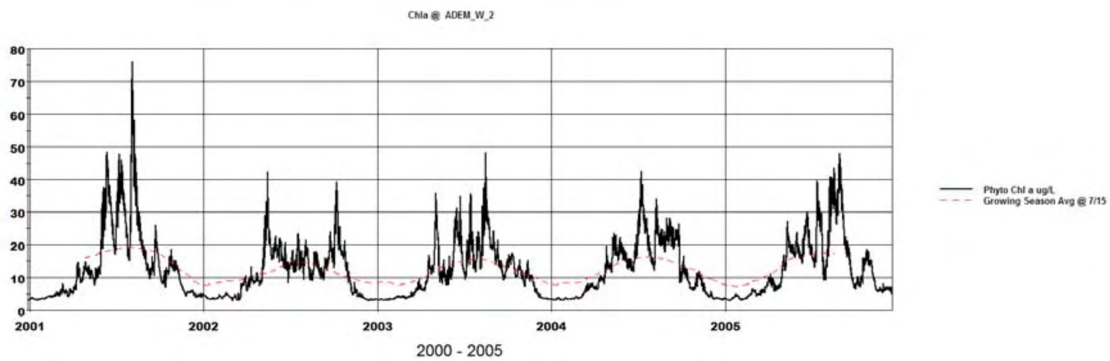

Figure 49: Example TMDL Chl a at Alabama Weiss 2 – Critical Segment Station

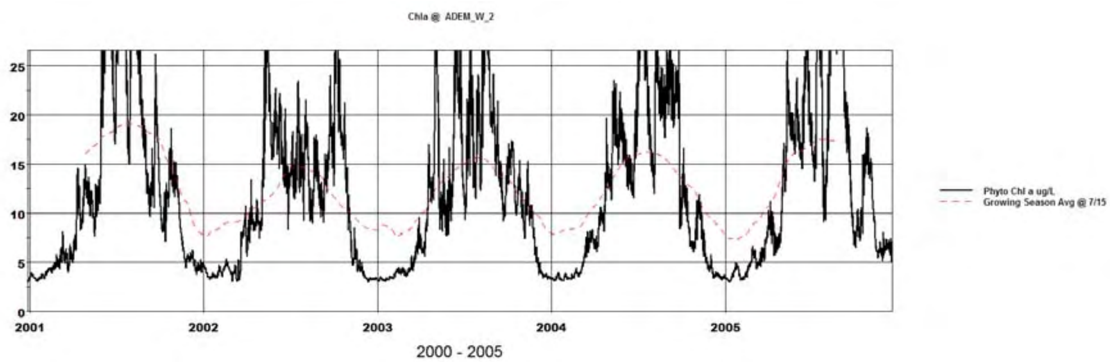

Figure 50: Example TMDL Chl a (zoomed in) at Alabama Weiss 2 – Critical Segment Station

Table 13: Lake Weiss Growing Season Average Chl *a* Data and Model Results 2001 - 2005

Year	Weiss 2		Weiss 1	
	Actual	TMDL	Actual	TMDL
2001	33	19	23	10
2002	25	15	17	7
2003	24	16	22	10
2004	27	17	20	5
2005	28	18	22	6

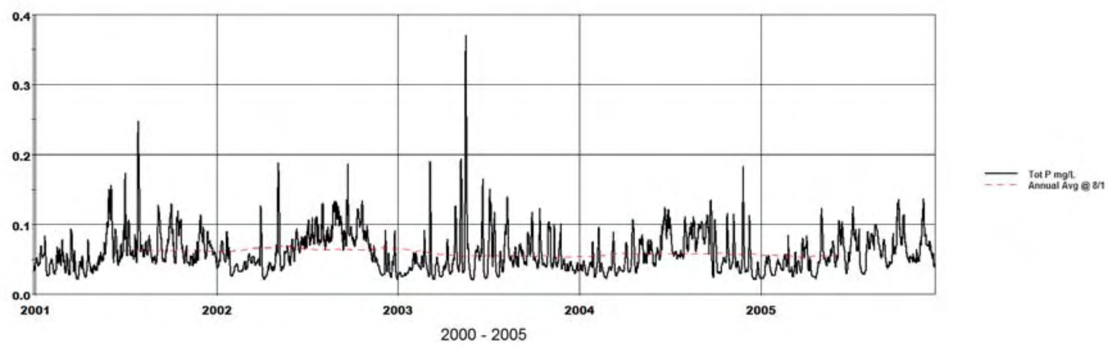

Figure 51: Coosa River Total Phosphorus at State Line

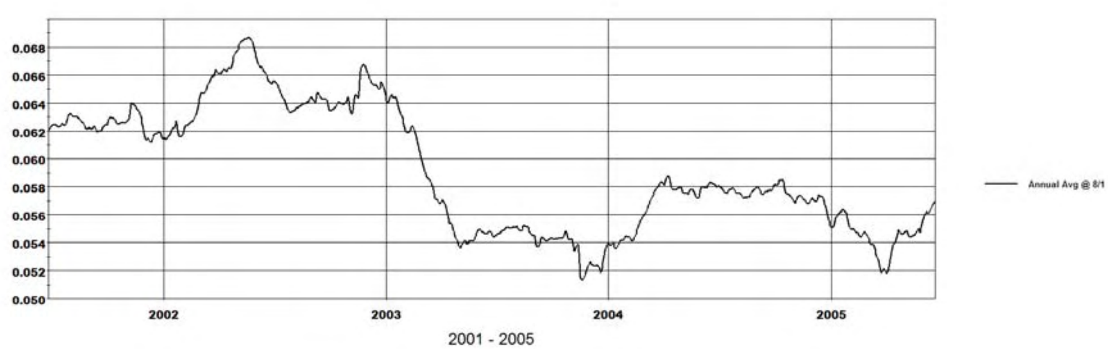

Figure 52: Growing Season Median (running 240 day average) of Total Phosphorus at State Line

Table 14: Growing Season Median TP at State Line

Year	TMDL
2001	0.062
2002	0.063
2003	0.055
2004	0.058
2005	0.057